

# Growth and Fusiform Rust Responses of Piedmont Loblolly Pine After Several Site Preparation and Regeneration Methods<sup>1</sup>

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**ABSTRACT.** *Cutover pine-hardwood sites in the Piedmont of central Georgia were prepared by prescribed burning or drum chopping and regenerated to loblolly pine (Pinus taeda L.) by planting or direct-seeding. Site preparation had little effect on soil physical properties. After an average of 12 years, trees were larger in dbh and total height, the merchantable stand was greater, and distribution was more uniform on planted than on seeded areas. Regeneration from direct-seeding was enhanced more by intensive site preparation than was regeneration from planting. Neither fusiform rust incidence nor rust associated mortality*

*was affected consistently by the intensity of site preparation, but both rust incidence and rust associated mortality were generally higher in the direct-seeded than in the planted plots.*

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After natural stands containing mixtures of pine and hardwood are harvested from upland sites on the Piedmont Plateau, most foresters recommend mechanical site preparation and planting of 1-0 loblolly pine seedlings. The purpose of mechanical site preparation is to reduce competition from residual, unmerchantable hardwoods as well as sprouts of harvested hardwoods. Particularly for nonindustrial private forest owners, however, foresters should be offering a range of options that may vary in effectiveness as well as cost and appearance. Prescribed burning and direct-seeding can

reduce costs, but at some price in productivity of the new stand (Brender 1973).

Of equal importance to seedling establishment is how the intensity of site preparation and the regeneration method affect the subsequent incidence of fusiform rust caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme*. In slash pine (*P. elliottii* Engelm. var. *elliottii*), both height growth and rust incidence generally have been greater with increasing intensity of site preparation (Burton et al. 1985, Miller 1977). Studies on loblolly pine, however, have failed to demonstrate a consistent relationship between intensity of site preparation and rust incidence (Miller 1977). Recent research by Zutter et al. (1987) found that herbaceous weed control increased the incidence of stem galls in loblolly pine plots on six of seven sites in North Carolina, Georgia, and Alabama that had received several different mechanical site preparation treatments, but the increases after 5 years were statistically greater at only two sites.

The purposes of our study were to: (1) compare regeneration of loblolly pine by direct-seeding and by hand planting, (2) determine if intensive site preparation is needed to obtain well-stocked pine stands, and (3) assess the influence of site preparation and regeneration methods on subsequent infection of seedlings by fusiform rust. Damage by tip moths (*Rhyacionia frustrana* Comst.) for 1-3 years after stand establishment was reported by Thomas et al. (1982). In this paper, we present 12th-year results.

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Trade names mentioned in this paper are for information only and do not constitute an endorsement by the USDA Forest Service.

## SITE DESCRIPTION AND METHODS

In 1968, 1969, and 1970, two blocks containing all study treatments were installed per year at a total of six locations (Table 1) on timberland controlled by the industrial cooperator in the lower Piedmont of central Georgia (Figure 1). In Monticello, in Jasper County, at the same latitude and about midway between the field locations, mean temperature is 46°F in January and 81°F in July. The growing season averages 232 days. About half of the annual precipitation of 50 in. occurs during the growing season, mostly from thunderstorms. Brief periods of drought are common during the late spring and fall. All study sites were located in the area of Georgia designated by Squillace (1976) as high hazard for fusiform rust- Jones and Putnam Counties 70 + %, Meriwether County 80 + %.

Areas from which mature natural stands of pine and hardwood recently had been commercially clearcut were selected for study. The harvested stands were typical of nonindustrial private holdings that are being harvested on the Piedmont. Loblolly pine had been the predominant overstory species, but scattered shortleaf pines (*P. echinata* Mill.) were also present (Table 1). In both numbers and basal area, the hardwood stand component was dominated by sweetgum (*Liquidambar styraciflua* L.) and flowering dogwood (*Cornus florida* L.). Soils are

well-drained, sandy loam to sandy clay loam Ultisols, in the Cecil, Madison, and Davidson series (clayey, kaolinitic, thermic Typic Hapludults, and Rhodic Paleudults). Slope gradients ranged from about 5 to 20%.

A representative 6-ac block was selected at each site. Each treatment block was divided into two

sub-blocks, with each sub-block prepared by one of two methods. Preparation treatments were made by the industrial cooperator under operational conditions:

1. *Burn*. Prescribed strip headfires during the late growing season were timed for maximum reduction of litter and logging debris. Prior to burning, hardwood stems

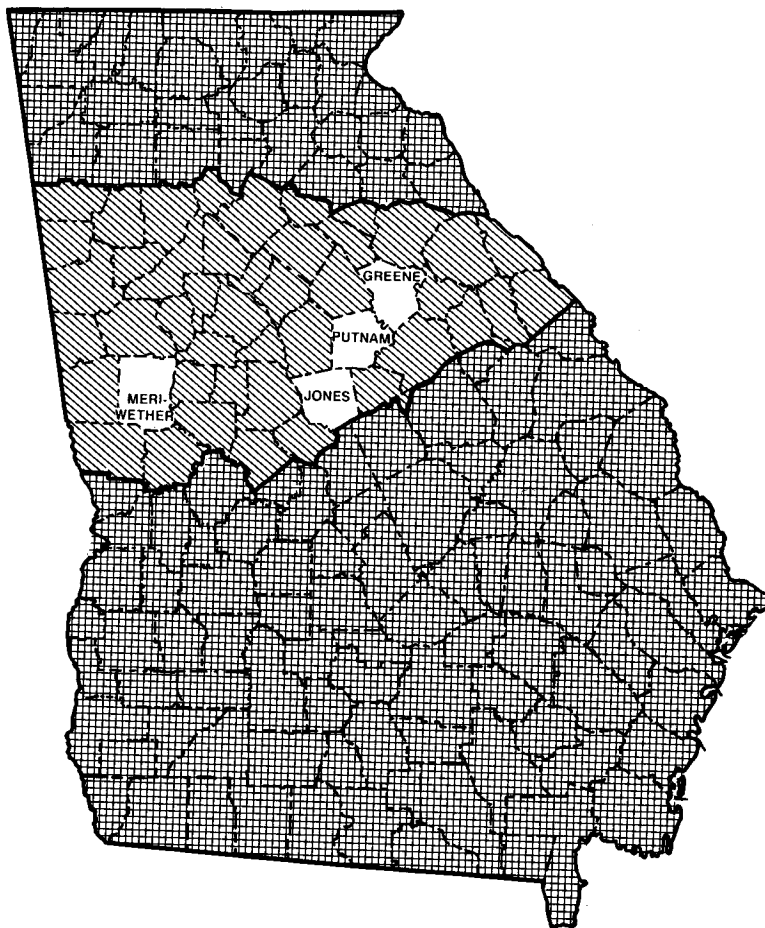


Figure 1. Counties in the Georgia Piedmont where the study was conducted.

Table 1. Location, treatment date, and characteristics of the six experimental sites in the Piedmont of Georgia.

Block No.	County	Treatment date	Soil series	Site index <sup>a</sup>	Pretreatment			
					Stocking		Basal area	
					H w d	Pine	H w d	Pine
					No./ac		ft <sup>2</sup> /ac	
I	Jones	2/1968	Davidson	80	1187	358	26	96
II	Greene	2/1968	<sup>b</sup>	75	765	277	31	66
III	Jones	2/1969	Davidson	80	820	268	31	91
IV	Meriwether	2/1969	Madison	95	640	253	16	76
V	Meriwether	2/1970	<sup>c</sup>	368	66	16	28	
VI	Putnam	2/1970	Cecil	60	494	538	34	41

<sup>a</sup> Loblolly pine at 50 years of age.

<sup>b</sup> Soil series not available.

<sup>c</sup> Measured site index not available but estimated to be about 70.

>2 in. dbh were injected with undiluted 2,4-D amine.

2. **Chop.** During the late growing season, when soil moisture was low, one pass was made with a tandem, 2-ton offset drum chopper pulled by a Caterpillar D8-size crawler tractor.

Weather conditions during the site preparation treatments were not recorded.

Effects of site preparation on some soil physical properties were evaluated in a preliminary study.<sup>2</sup> Immediately before and after site preparation, soils in Blocks 1 and II were sampled to determine capillary and noncapillary porosity and bulk density. Undisturbed cores were taken from 12 sampling locations at the 0- to 3-in. and 3- to 6-in. soil depths.

After site preparation, each 3-ac sub-block was divided into three plots and randomly assigned a regeneration treatment:

1. **Plant.** 1-O loblolly pine seedlings were hand planted at an average spacing of 6 x 8 ft.
2. **Broadcast.** Seeds were applied at a rate of 1 lb/ac with a hand-operated Cyclone seeder.
3. **Row.** About 400 seeds were applied per 100 ft of row (equivalent to about 0.5 lb of seeds/ac). Rows were 8 to 10 ft apart.

All seeds were from a natural stand seed-production area maintained by the industrial cooperator in Monroe County, GA (Figure 1). Germination of full seeds averaged 91% in tests, and seed numbers averaged 19,500/lb. With the exception of Blocks 1 and II, all direct seeding regeneration treatments were made during the late winter using seeds stratified by moist storage at 35°F for 30 days. Blocks 1 and II were seeded with unstratified seeds during the early fall using a mechanical device mounted on the drum chopper by the method of Campbell (1965). The other four blocks were row-seeded with a hand-

operated Panama direct-seeder with a 1 1/32 in. bushing for loblolly pine seed. All sown seeds were treated with repellants effective against birds and rodents.

A 1/2-ac measurement subplot (149 ft<sup>2</sup>) was established in the center of each regeneration plot. The sampling procedures for determining treatment responses varied among regeneration methods. In broadcast-seeded areas, 50 permanently marked milacre plots were systematically established over the measurement subplots. In row-seeded areas, 50 permanently marked milacre plots were systematically located in five randomly selected rows (10 plots/row). In the planted areas, five randomly chosen rows were selected and permanently marked for measurement, and all trees in each sample row were measured. Measurements on milacre plots and sample rows were taken after one, two, three, and five growing seasons. Final measurements were made in 1980, when the trees were 11, 12, and 13 years old. Part of Block VI was destroyed by wild-fire shortly after establishment, and subsequently, data were collected only from the mechanically chopped subblock, which was not measured at the last inventory.

Data collected included total number of living trees, height of dominant seedlings, and hardwood competition class. A single dominant tree was counted and measured on milacre plots of direct-seeded areas during the final inventory to define the merchantable stand. Stem diameter was measured when tree height reached 4.5 ft. Tree mortality was recorded, and its likely cause noted if discernible. On areas regenerated by direct-seeding, stocking was calculated as the percent of the total milacre plots having one or more pine seedlings. Stocking percent on the planted areas was calculated as the proportion of actual trees present to the maximum number possible based on the mean spacings within measurement rows and the total number of rows in each sub-block.

The hardwood stand on each

sub-block was sampled at the last inventory. Twelve 1/250-ac circular plots were systematically established on each 1/2 ac measurement subplot; all trees >0.5 in. dbh were identified by species, and dbh was recorded to the nearest inch. Total height to the nearest foot was determined on two hardwood saplings nearest the plot center. The hardwood stand data were combined into three major species groups: oaks (*Quercus* spp.), major miscellaneous species (f lowering dogwood and sweetgum), and minor miscellaneous species [yellow-poplar (*Liriodendron tulipifera* L.), black cherry (*Prunus serotina* Ehrh.), and others]. Pines were also inventoried on these 1/250-ac plots to provide a basis for comparison with the hardwood stand.

For the final inventory, the merchantable portion of the stand was defined as trees 5.0 in. dbh and larger. Cubic volume outside bark was estimated from dbh and total height using a locally developed prediction equation (D. R. Phillips, pers. comm. 1987).

Incidence of fusiform rust was recorded on the same measurement schedule as the silvicultural data and was accumulated to provide total cumulative rust incidence in each treatment combination through 5 and 11, 12, or 13 growing seasons. Trees were scored as infected if they had a gall on the central stem or on a living branch within 6 in. of the stem. All dead trees with stem galls were assumed to have been killed by fusiform rust and are reported as cumulative rust-associated mortality (RAM). In the direct-seeded plots, fusiform rust data was collected on all seedlings in the milacre quadrats rather than only on the dominant seedlings. Also, data for the broadcast and row seeded plots were combined.

Results for each regeneration method are analyzed separately for significant effects of site preparation. Because variances associated with the sampling scheme used in each regeneration method were not homogeneous, variables

<sup>2</sup> Nelson S. Loftus, Jr. 1967. The effect of site preparation methods on soil physical conditions and seedling development. Study plan on file. Southeast. For. Exp. Stn., Asheville, NC.

dealing with area measures (tree stand, basal area, etc.) were not tested statistically. However, site-preparation methods within a regeneration method (for example, burned vs. chopped on planted areas) could be compared validly as could dbh, height, and rust incidence of individual trees. All tests of significance were made at the 5% levels.

## RESULTS AND DISCUSSION

### Site Preparation

Drum chopping consistently produced a uniform appearing site by severing logging debris and small residual pine and hardwood stems into small pieces and partially mixing them with soil. Large hardwood trees were pushed over and partially uprooted. In contrast, prescribed burning produced variable results, with effectiveness apparently depending on the distribution of logging debris. Where logging debris was not present, fire intensity often was insufficient to top-kill hardwoods or patches of green herbaceous vegetation, such as grasses and Japanese honeysuckle (*Lonicera japonica* Thunb.). As might be expected, burning effectiveness differed visibly among blocks.

The significant effects of site preparation on physical soil characteristics in Blocks I and II are presented in Table 2. Prescribed burning had no significant effects on soil properties. The drum chopping treatment significantly increased capillary (retention)

**Table 2. Mean values of pore space in the 0-3 and 3-6 in. of soil before and after drum chopping site preparation treatment of Blocks I and II in the Georgia Piedmont.<sup>a</sup>**

Site preparation treatment	Soil porosity <sup>b</sup>	
	Capillary	Noncapillary
	percent by volume	
	Soil depth 0-3 in.	
Before chopping	30.7 A	25.5 A
After chopping	35.0 B	20.7 B
	Soil depth 3-6 in.	
Before chopping	31.0 A	19.6 A
After chopping	33.0 B	16.5 B

<sup>a</sup> Progress Report. Nelson S. Loftus, Jr. 1968. The effect of site preparation methods on soil physical conditions and seedling development. On file, Southeast. For. Exp. Stn., Macon, GA.

<sup>b</sup> Within a soil depth and soil porosity category, means followed by the same capital letter are not significantly different (5% level).

pore space and significantly decreased noncapillary (detention) pore space, but total pore space was not affected. Bulk density, a measure of compactness and total porosity, was not significantly different for either block location or soil layer.

### Total Stand

At 12 years, method of regeneration appears to have a greater effect on the proportion of area occupied by trees (stocking percent) than did site preparation treatment (Table 3). Average stocking percent was greater on the planted plots (54%) than on the average of all direct-seeded plots (43%). Even though stocking was relatively low on direct-seeded plots, it was still above the 40% level suggested by Brender (1973) as minimally acceptable.

Total tree height was greater on chopped plots than on burned plots (Table 3). At the final mea-

surement, the height advantage of trees on chopped subblocks ranged from about 4 ft on planted plots to 9 ft on broadcast-seeded plots. Trees averaged 5 ft greater in total height on planted plots than on both direct-seeded treatments.

Mean dbh followed a relationship similar to that of total height (Table 3). Trees were significantly larger in diameter on chopped plots, with the exception of regeneration by broadcast seeding. Although trees were larger on planted plots, part of this advantage could have resulted from the 1-year greater age of the planted than the seeded trees.

Basal area was much greater in planted than in direct-seeded stands (59 vs. 34 ft<sup>2</sup>/ac) and slightly greater on broadcast-seeded plots (37 ft<sup>2</sup>/ac) than on row-seeded plots (30 ft<sup>2</sup>/ac) (Table 3). Basal area of the stand was significantly greater on direct-seeded

**Table 3. Mean characteristics of the loblolly pine stand 12 years after planting or direct-seeding on 6 blocks in the Georgia Piedmont site prepared by burning or chopping.**

Site prep <sup>a</sup>	Tree stand (no./ac)	Tree stocking (%)	Total height (ft)	Dbh (in.)	Basal area (ft <sup>2</sup> /ac)
		Hand plant			
Burned	502A	55A	28A	4.2A	53A
Chopped	480A	53A	32A	4.8B	65A
		Broadcast-seeded			
Burned	388A	39A	20A	3.2A	27A
Chopped	432A	43A	29B	4.2A	47B
		Row-seeded			
Burned	315A	44A	23A	3.2A	23A
Chopped	321A	46A	28B	4.4B	38B

<sup>a</sup> Within a regeneration method, site preparation treatment means followed by the same capital letter are not significantly different (5% level).

Table 4. Mean characteristics of the merchantable loblolly pine stand 12 years after planting or direct-seeding on six blocks in the Georgia Piedmont site prepared by burning or chopping.

Site prep <sup>a</sup>	Tree stand (no./ac)	Total height (ft)	Dbh (in.)	Basal area (ft <sup>2</sup> /ac)	Cubic volume (ft <sup>3</sup> /ac)
Hand plant					
Burned	144A	33A	5.7A	26A	800A
Chopped	234A	35A	5.8A	44A	1045A
Broadcast-seeded					
Burned	44A	29A	6.0A	9A	367A
Chopped	136B	33A	6.0A	27B	739B
Row-seeded					
Burned	39A	31A	5.6A	14A	346A
Chopped	108B	33A	6.1A	22A	594B

<sup>a</sup> Within a regeneration method, site-preparation treatment means followed by the same capital letter are not significantly different (5% level).

plots prepared by chopping than on burned plots. Method of site preparation had little effect on stand basal area of the planted plots.

#### Merchantable Stand

In general, characteristics of the merchantable loblolly pine stand were similar and proportional to the total stand (Table 4). For each regeneration method, site preparation by chopping resulted in a merchantable stand with more trees that were taller and larger in dbh. Consequently, basal area and cubic volume were also greater on these blocks. For the planted stands, there was no significant difference between the burning or chopping treatment. Using a conversion factor of 90 ft<sup>3</sup>/rough cord outside bark, the planted pine stands contain an average of 10 cords/ac at 12 years, whereas stands on the broadcast- and row-

seeded plots have about 6 and 5 cords each.

#### Fusiform Rust

Cumulative fusiform rust incidence and RAM are shown by block, site treatment, and regeneration method in Tables 5 and 6. Overall, there were no consistent differences in rust incidence that could be related to site treatment. The only statistically significant differences were in block 1 for mean rust, chopped (43%) vs. burned (25%) and chopped, seeded (54%) vs. burned, seeded (25%) (Table 5). Generally, rust incidence was higher in seeded plots than in the planted (eight of nine), and these differences were statistically significant in four of the eight possible comparisons across both site treatments (Table 5).

Cumulative RAM was also highly variable between the two

site treatment methods, with a significant difference only in Block I, chopped, seeded (24%) vs. burned, seeded (9%) (Table 6). As was true for incidence, RAM was generally greater in the seeded plots (six of nine), with the differences in four of the six possible comparisons being statistically significant (Table 6).

The generally greater rust incidence and RAM in the seeded plots were not unexpected for several reasons. In the first year at each site, the newly emerging seedlings would have been from about 10 to 16 weeks old when the maximum danger of fusiform rust infection occurs in this area of Georgia. Such seedlings would typically have a greater proportion of rapidly growing, potentially susceptible tissues than would be expected on the planted 1-O seedlings where growth would be more sporadic and less rapid during the

Table 5. Cumulative incidence of fusiform rust stem galls and living branch galls within 6 in. of the stem on loblolly pines II, 12, or 13 years after planting or direct-seeding on six blocks in the Georgia Piedmont site prepared by chopping or burning.

Block	Years	Chopped			Burned		
		Planted	Seeded	Mean	Planted	Seeded	Mean
.....%, rust <sup>a</sup> .....							
I	13	31	54 B,C	43 A	24	25	25
II	13	31	50 c	41	21	47 c	34
III	12	32	34	33	41	b	—
IV	12	52	69 C	61	61	b	—
V	11	56	55	56	50	62	56
VI	5 <sup>d</sup>	12	18	15	c	c	—
Mean <sup>e</sup>		40	52	47	39	45	38

<sup>a</sup> Capital letters designate statistically significance differences (5% level); A = mean rust incidence chopped, planted and seeded vs. planted and seeded; B = chopped, seeded vs. burned, seeded; C = seeded vs. planted within a site treatment.

<sup>b</sup> Number of sample seedlings inadequate.

<sup>c</sup> Plots destroyed by wildfire.

<sup>d</sup> Not measured in 11th year.

<sup>e</sup> Excluding 5-year data from Block VI.

Table 6. Cumulative rust associated mortality (RAM) of fusiform rust infected loblolly pines II, 12, or 13 years after planting or direct seeding on six blocks in the Georgia Piedmont site prepared by chopping or burning.

Block	Years	Chopped			% rust <sup>a</sup>	Burned		
		Planted	Seeded	Mean		Planted	Seeded	Mean
I	13	7	24 A,B	15		6	9	8
II	13	7	28 B	17		5	23 B	14
III	12	13	7	10		14	b	—
IV	12	33	46	39		30	b	—
V	11	20	18	19		12	26	19
VI	5 <sup>d</sup>	12	8	10		c	c	—
Mean <sup>e</sup>		16	24	20		13	19	14

<sup>a</sup> Capital letters designate statistically significance differences (5% level); A = mean rust incidence chopped, planted and seeded vs. chopped, seeded vs. burned, seeded; B = seeded vs. planted within a site treatment.

<sup>b</sup> Number of sample seedlings inadequate.

<sup>c</sup> Plots destroyed by wildfire.

<sup>d</sup> Not measured in 11th year.

<sup>e</sup> Excluding 5-year data from Block VI.

same period. Also, rust infections of such young seedlings occur mainly on the stem or short branches and are usually lethal. Finally, the mortality of stem-infected seedlings in direct seeded plots may be accelerated by the increased competition in seeded plots with large numbers of seedlings in a relatively small growing space.

The incidence of fusiform rust and RAM on these sites in the high rust hazard areas of the Georgia Piedmont were not affected in any consistent way by either of the two site preparation methods. For regeneration methods, the direct seeded plots were generally more severely affected by rust than were the planted seedlings. Across all six site sites, however, the mean milacre stocking of direct-seeded plots was reduced 13.5% by RAM compared to a mean RAM of 14.5% in the planted areas. While the RAM was nearly equal between the planted and seeded plots, the biological and economic impacts were more severe in the seeded areas because of the initially lower and generally less uniform stocking.

#### Hardwood Stand

Neither site preparation treatment eliminated hardwood competition (Table 7). Both the hardwood stand density and basal area

were slightly greater after chopping than after burning. Sweetgum and flowering dogwood were the most abundant competing species, accounting for 44% of all stems present and about two of every three hardwoods. The number of *Quercus* spp., mostly laurel oak (*Q. laurifolia* Michx.) and southern red oak (*Q. falcata* Michx.), were about equal for the two methods of site preparation, but the oaks were larger in diameter on plots prepared by chopping, as shown by the greater basal area (4 vs. 3 ft<sup>2</sup>/ac). In the final inventory, over twice as many hardwood as pine stems (1,914 vs. 916/ac) were present on the average plot, but the pines had over three times the basal area. Average stand density and height of the hardwood stand, by dbh class, were:

Dbh class (in.)	Stand density (no./ac)	Total height (ft)
1	1,563	14
2	295	21
3	44	26
4	12	29

The distribution of hardwood stand density and total height was similar for the three species groups. Average hardwood height by dbh class did not differ between site preparation methods. In portions of some study areas, hardwood height equalled or exceeded height of the pine stand, indicating continued competition.

#### CONCLUSIONS AND IMPLICATIONS FOR MANACEMENT

Site preparation method had little effect on soil physical proper-

Table 7. Mean stand and basal area of hardwood species groups and all pines 12 years after planting or direct-seeding on six blocks in the Georgia Piedmont site prepared by burning or chopping.

Species groups	Total stand			Total basal area		
	Burned	Chopped	Mean (%)	Burned	Chopped	Mean (%)
		(no./ac)			(ft <sup>2</sup> /ac)	
Oaks <sup>a</sup>	330	322	12	3	4	4
Major spp. <sup>b</sup>	1115	1396	44	9	14	15
Minor spp. <sup>c</sup>	304	361	12	3	3	4
Total	1749	2079	68	15	21	23
Pines <sup>d</sup>	1032	801	32	54	67	77
Total all	2781	2880	100	69	88	100

<sup>a</sup> Mainly *Quercus laurifolia* and *Q. falcata*.

<sup>b</sup> *Liquidambar styraciflua* and *Cornus florida*.

<sup>c</sup> *Liriodendron tulipifera*, *Prunus serotina*, and other less abundant species.

<sup>d</sup> *Pinus echinata* and *P. taeda*.

ties, but drum chopping produced a more homogeneous site for regeneration. Also, at age 12, trees on chopped sites were somewhat larger than on prescribed burned sites. As a low cost alternative to mechanical site preparation, prescribed burning resulted in average stands and stockings about the same as that produced on sites prepared by drum chopping.

Regeneration by planting consistently produced more uniform and better stocked stands than either method of direct-seeding. Direct-seeding did not consistently produce a uniformly, well-stocked stand of loblolly pine, even though some improvements have been made in seeding techniques (Lance 1984). However, direct-seeding results were satisfactory enough so that it could be used for certain purposes, such as a low cost alternative to regeneration by planting or to increase stocking levels in young stands (Hazel et al. 1989).

The overall results of this study relative to fusiform rust indicate that the choice between site preparation by chopping and burning and regeneration by planting or

direct seeding in this area of the Georgia Piedmont can be made on the basis of factors such as anticipated survival and subsequent growth and yield rather than on the potential danger of increased rust incidence and severity, assuming adequate stocking and relatively uniform seedling distribution can be obtained by direct seeding.

Hardwoods will be a major component of pine stands in the Georgia Piedmont, regardless of the intensity of site preparation, unless intensive and costly herbicide treatments are made. In many cases, mixed species stands can be economically regenerated and managed with little loss in pine growth (Phillips and Abercrombie 1987) and those stands may have increased value for other uses, such as wildlife resources. □

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